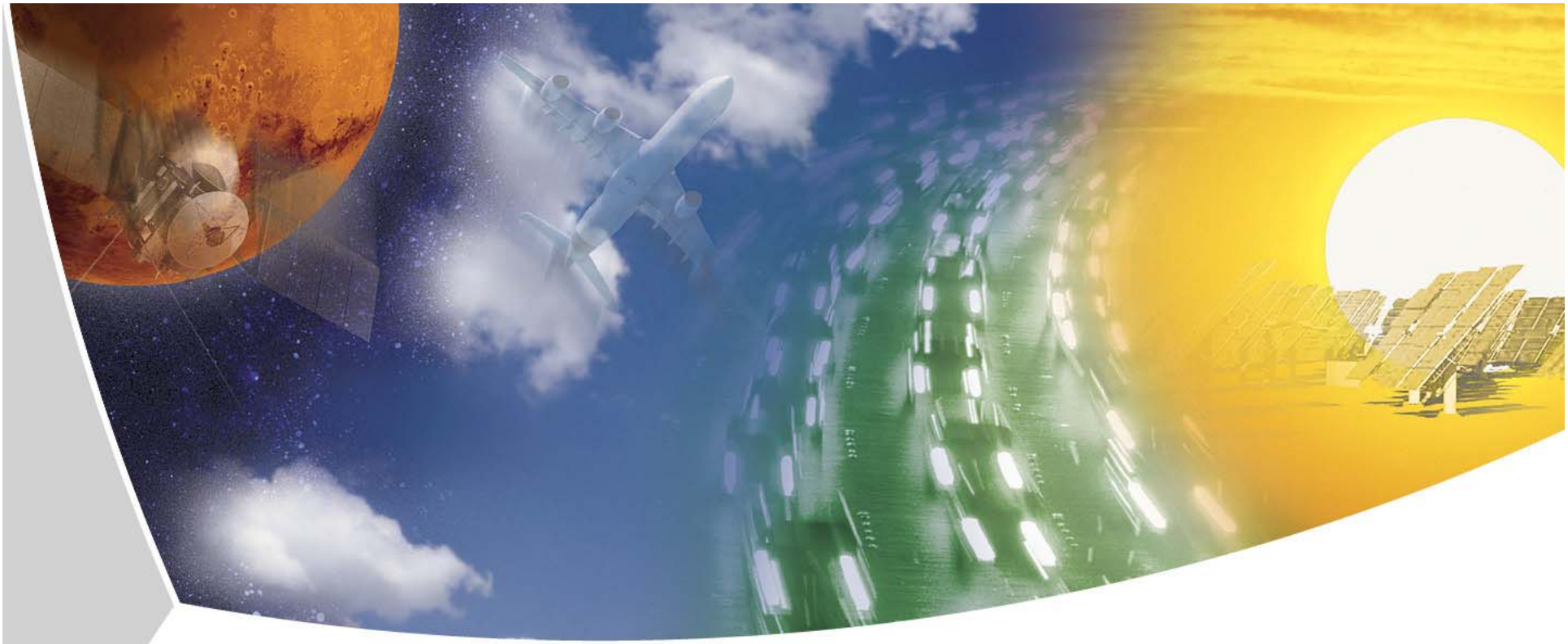

Processing and distribution of scintillation related data based on the high rate real time network EV*net*

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AEROSPACE AND DEFENCE, S.A.

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in der Helmholtz-Gemeinschaft

Overview

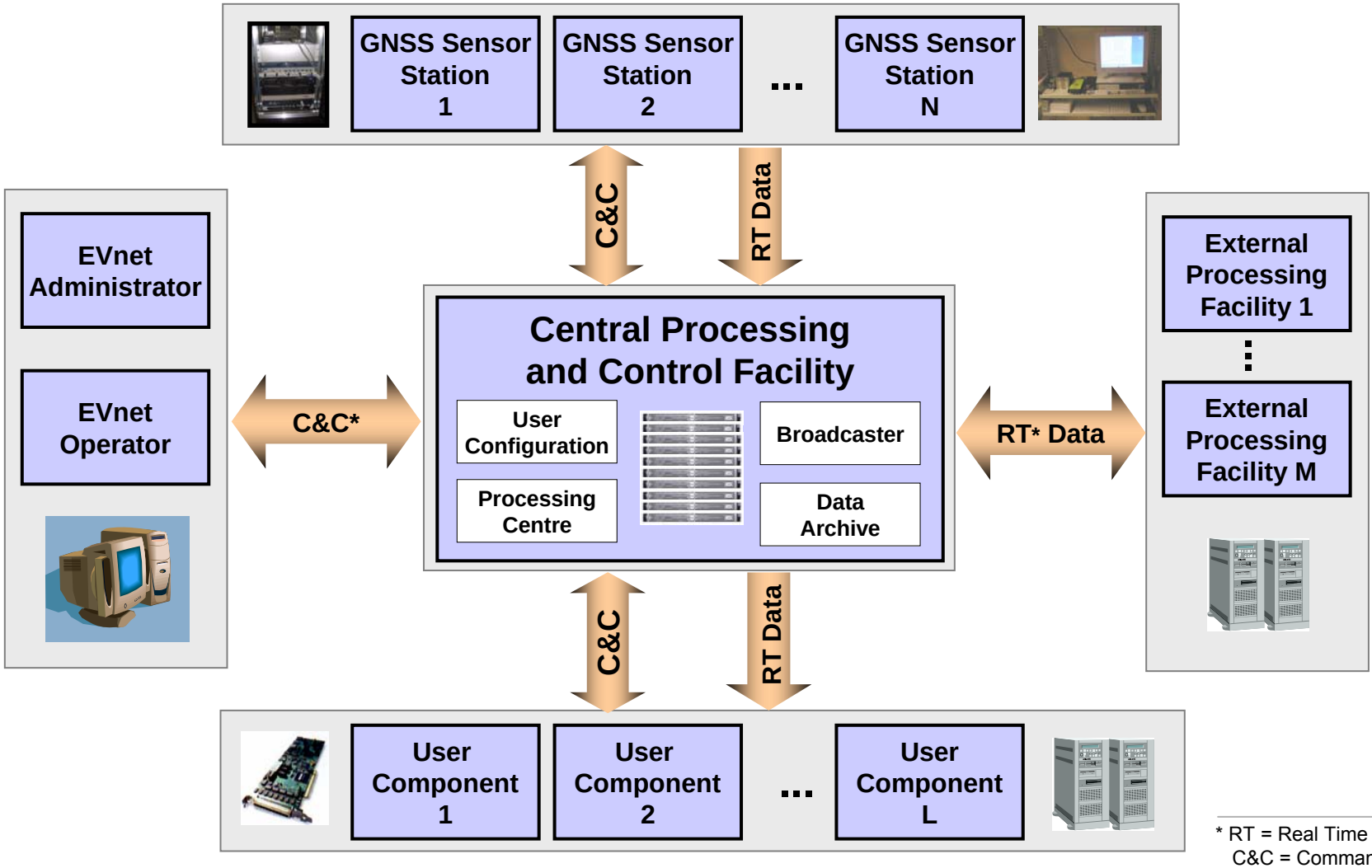
- EVnet (Experimentation and Verification Network)
  - → Overview
  - → Architecture
  - → Measurement Network
  - → Data streams
  - → Online Demo (Operator GUI)
- PRIS (Prediction of Ionospheric Scintillations)
  - → Data Collection and Processing Centre
  - → Real Time Capability
  - → Scintillation Processing Module
  - → Online Demo (Scintillation Monitor)
- Comparison between GSV4004 and Javad receivers
- Summary

EVnet – Short Profile

Near real-time network based on modular configurable and adaptable hardware and software components to complement the functionality, performance and verification of existing and future GNSS systems to deal as basic platform to support monitoring systems

- ✓ operates currently in a mode to receipt, process, and archive spatial distributed GNSS data (e.g. raw data, positioning data, NMEA data etc.) as well as meteorological data.
- ✓ enables high rate data transfer rates (up to 1 Mbps per sensor)
- ✓ supports up to 50 remote stations and up to 100 user components
- ✓ developed under a platform independent software design (Linux, Win2000/XP)
- ✓ based on TCP/IP connections via Internet (internet streaming technologies → Icecast broadcaster)
- ✓ authentication and encryption via secure shell
- ✓ enables the integration of external processing systems (e.g. software algorithms) by application interfaces (API)

EVnet - Basic Architecture



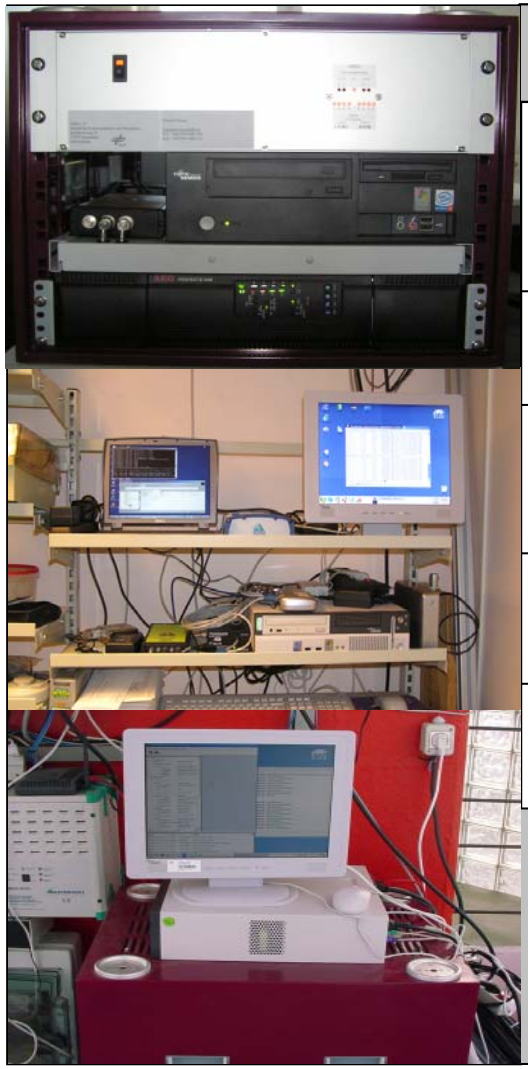
* RT = Real Time
C&C = Command & Control

EVnet – Master Remote Sensor Stations

Locations: 4 stations in Germany, 1 station in France	
Rack control	Monitoring of rack inside ambient conditions
GNSS Receiver Unit Receiver, Frequency Oscillator, Antenna Preamplifier, Antenna	Reception of GNSS signals (GPS, GLONASS, WAAS, EGNOS, GIOVE-A)
Weather Station Temperature, Air pressure, Humidity	Reception of weather data
Console Server	Monitoring of rack inside devices
Ethernet Switch	Provision of an internal TCP network
Server (PC)	Processing and data distribution
UPS	Increased system stability in case of power breaks
Switchable socket outlet	Flexible on/off functionality of devices

+ full remote control
+ expandable to up to 16 sensors
+ power break by-pass of around 1 hour
- inflexible for temporary installation

EVnet – Limited Remote Sensor Stations



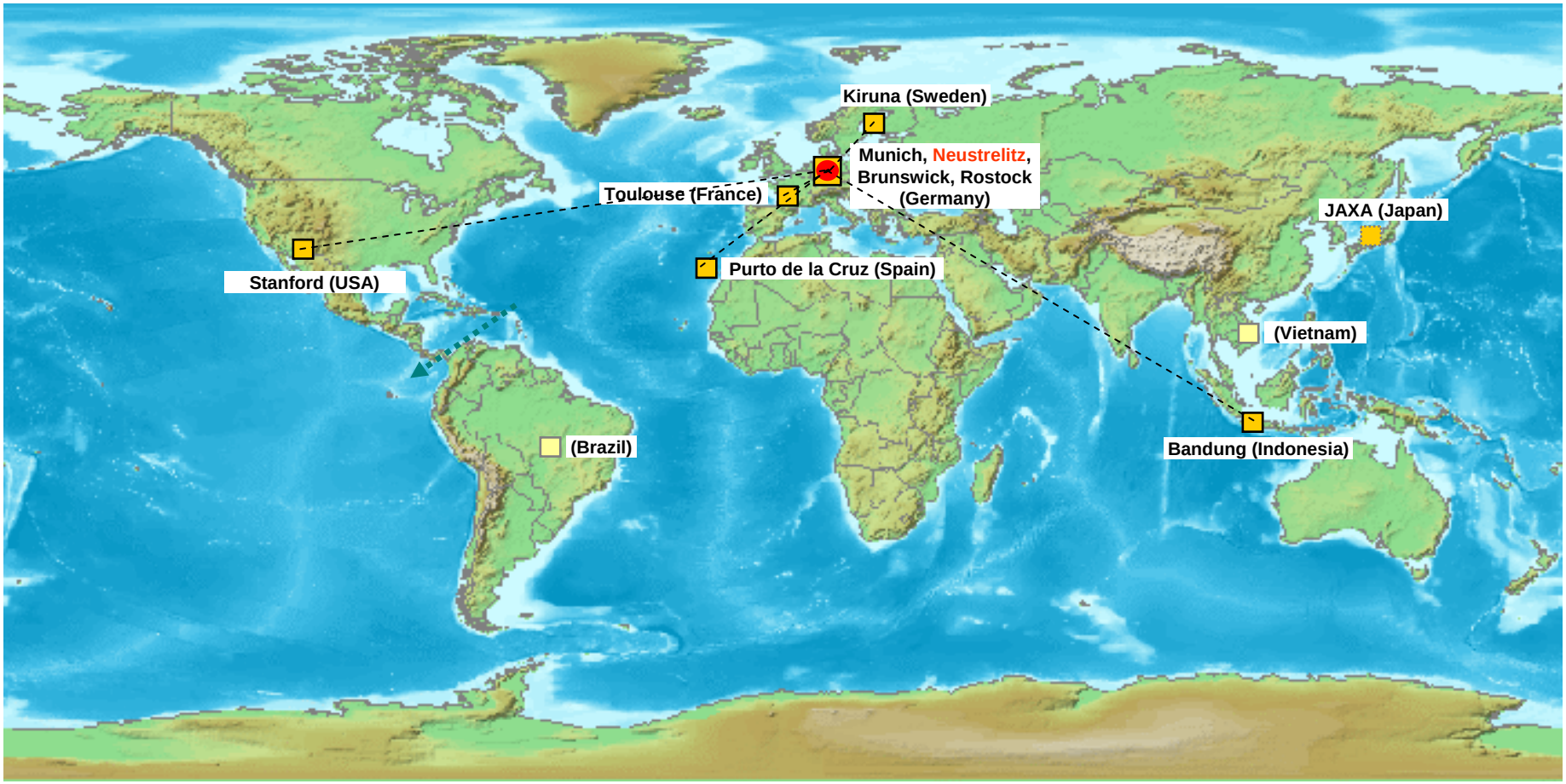
Locations: Stations in Indonesia, USA, Sweden, Canary Islands	
GNSS Receiver Unit Receiver, Frequency Oscillator, Antenna Preamplifier, Antenna	Reception of GNSS signals (GPS, GLONASS, WAAS, EGNOS, GIOVE-A)
Mini PC	Processing and data distribution
UPS	Increased system stability in case of power breaks
Weather Station	Reception of weather data
Ethernet Switch	Provision of an internal TCP network

+ very simple handling
+ developed for temporary installation
- limited power break (by-pass ~ 5 min)
- limited number of additional sensors

EVnet – Central Processing and Control Facility

Gateway	**Internet connectivity**
Admin Node	**Authentication, Set-ups**
Broadcaster	**Data distribution**
Processing Node	**Data processing**
Archive Node	**Data archiving**
RAID Storage-System	**Data archiving (max. 4 TB) RAID Level 5**
Console Server	**Device control**
Ethernet-Switch	**Internal Network Communication**

EVnet - Real Time Measurement Network (1)



- Sensor Station (operational)
- Sensor Station (in preparation)
- Sensor Station (potential candidate)
- Central Processing & Control Facility (CPCF)
- Real Time Data Streams

Status: February 2008

EVnet - Real Time Measurement Network (2)

All receivers deliver

- L1/L2
- GPS / GLONASS
- WAAS / EGNOS
- 50 Hz raw data
- 20 Hz position data
- amplitude values

Foreseen modifications

Operation of TOPCON NetG3 → GPS/GLONASS/Galileo

Location	Country	Hosting Company	Receiver	Data / Data rates
Neustrelitz	Germany	DLR	TOPCON EGGD+	50 Hz GNSS data, 1 Hz weather data
Munich	Germany	DLR	JAVAD LGGD	50 Hz GNSS data, 1 Hz weather data
Toulouse	France	SUPAERO	JAVAD LGGD	50 Hz GNSS data, 1 Hz weather data
Kiruna	Sweden	IRF	JAVAD LGGD	50 Hz GNSS data
Stanford	USA	Stanford University	JAVAD LGGD	50 Hz GNSS data, 1 Hz weather data
Tenerife	Spain	GMV	TOPCON EGGD+	50 Hz GNSS data, 1 Hz weather data
Bandung	Indonesia	LAPAN	JAVAD LGGD	25 Hz GNSS data
Rostock	Germany	DLR	TOPCON EGGD+	50 Hz GNSS data, 1 Hz weather data
Brunswick	Germany	DLR	TOPCON EGGD+	50 Hz GNSS data, 1 Hz weather data

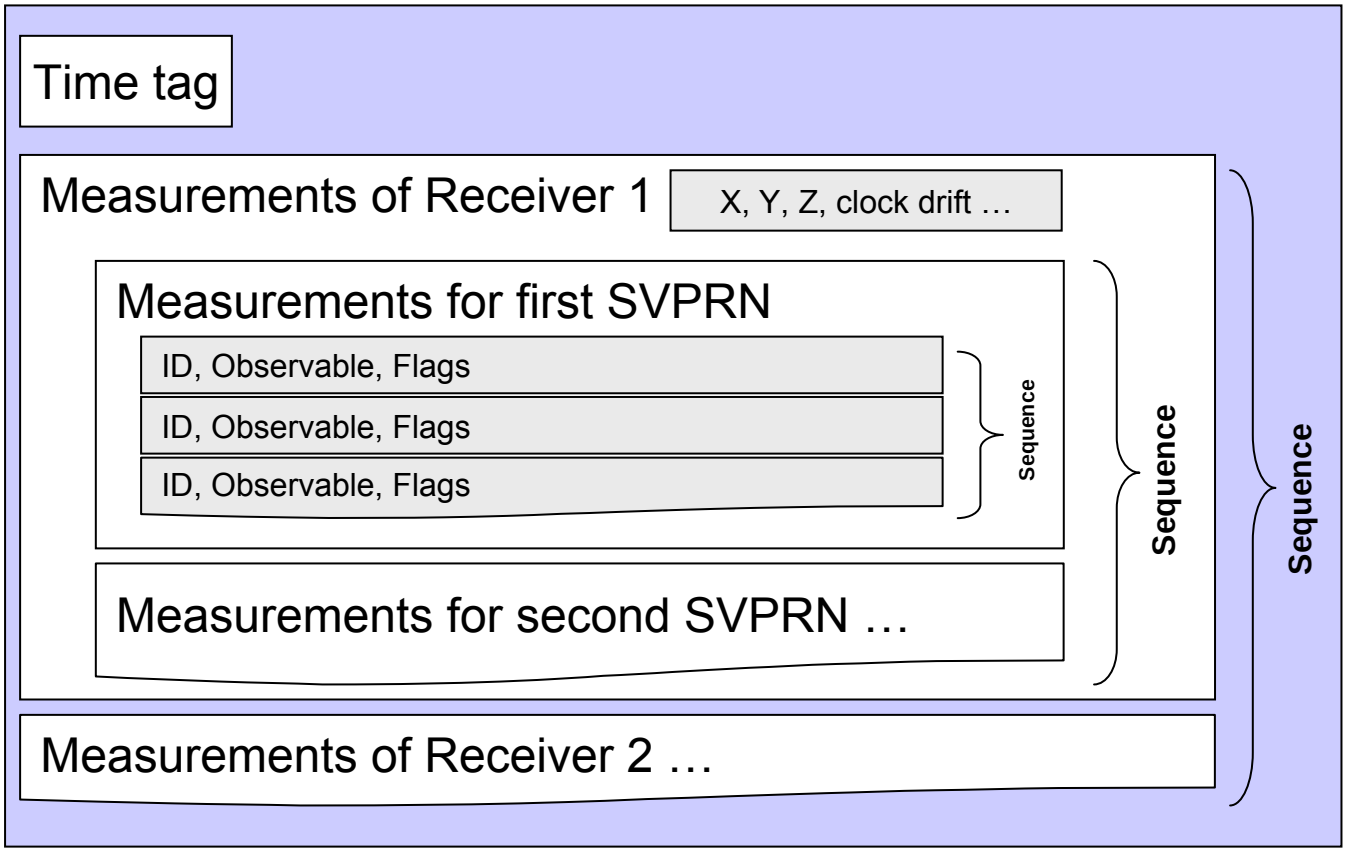
EVnet - RT data exchange formats (Overview)

Data type	exchange format	Comments
RT Raw data	proprietary receiver format (Topcon/Javad)	un-decoded data directly coming from each receiver
RT Multi-sensor data	ASN1.BER*	decoded and synchronized observation data of one or more receivers
RT Ephemeris data	RINEX2 (without header)	decoded navigation data delivered by one ore more receivers
RT Phase data	ASN1.BER	specific processed data describing the phase assessment of receivers
RT Amplitude data	ASN1.BER	specific processed data describing the amplitude assessment of receivers
RT Position data	ASN1.BER	estimated Position in X, Y, Z plus additional information (clock offset etc.)
RT Scintillation data	proprietary ASCII format (ESA PRIS project)	ionospheric relevant parameter like SigmaPhi, S4, TEC plus geometric parameter (Azimuth, Elevation angle)
RT Weather data	proprietary ASCII format	temperature, humidity, air pressure

* Similar to RINEX3 data structure

EVnet - Multi sensor protocol PDU (Protocol Data Unit)

A multi sensor PDU contains either an almanac, or an ephemeris or an epoch unit of observation data → Example for an Epoch choice unit



The Observables are identified by three character codes like in RINEX 3 format:
- e.g. C1C, C1P, L5A

Some new (in RINEX 3 unassigned) observable types are used to express higher level products.

- M*xx* → quality assessed phase (quality flag)
- N*xx* → phase prediction error
- G*xx* → amplitude noise variance

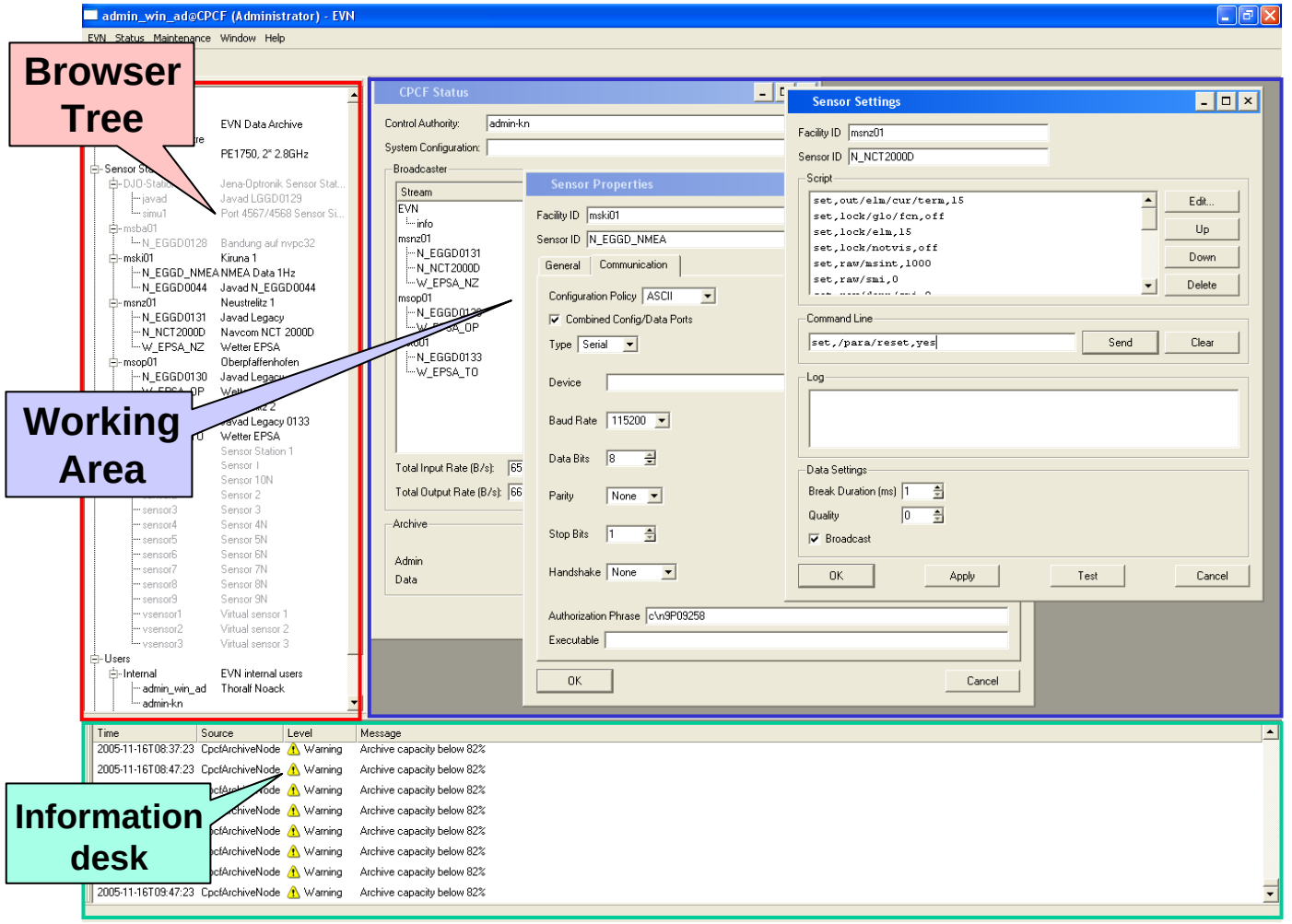
EVnet - Data Access

- ✓ Is provided by generic or specific EVnet client applications
- ✓ Generic client applications are available for Windows 2000/XP and Linux (certified for Suse 8.2, 9.x and Open Suse 10)
- ✓ Specific client applications (data assessment and monitoring) are developed by DLR
- ✓ API enables the directly access on data streams as part of specific applications (includes EVnet technologies into user specific SW)
- ✓ Access requires a secure shell (SSH) connection to the CPCF broadcaster
- ✓ User authentication via login, password and SSH-key is necessary
- ✓ Sufficient bandwidth is required to transmit RT data

EVnet - Interfaces

- **Download of real-time Data**
  - real-time Client Module
- **Access on EVnet Archive**
  - WWW Interface for interactive Access or
  - via XML Interface (access via user specific programs)
- **Upload of real-time Data**
  - Sensor stations or
  - by using of a specific real-time Source Module
- **Middleware Module**
  - Integration of Processing Algorithms
- **Limited access on sensor station for external users**
  - execution of independent measurement campaigns

EVnet – Command and Control Monitor



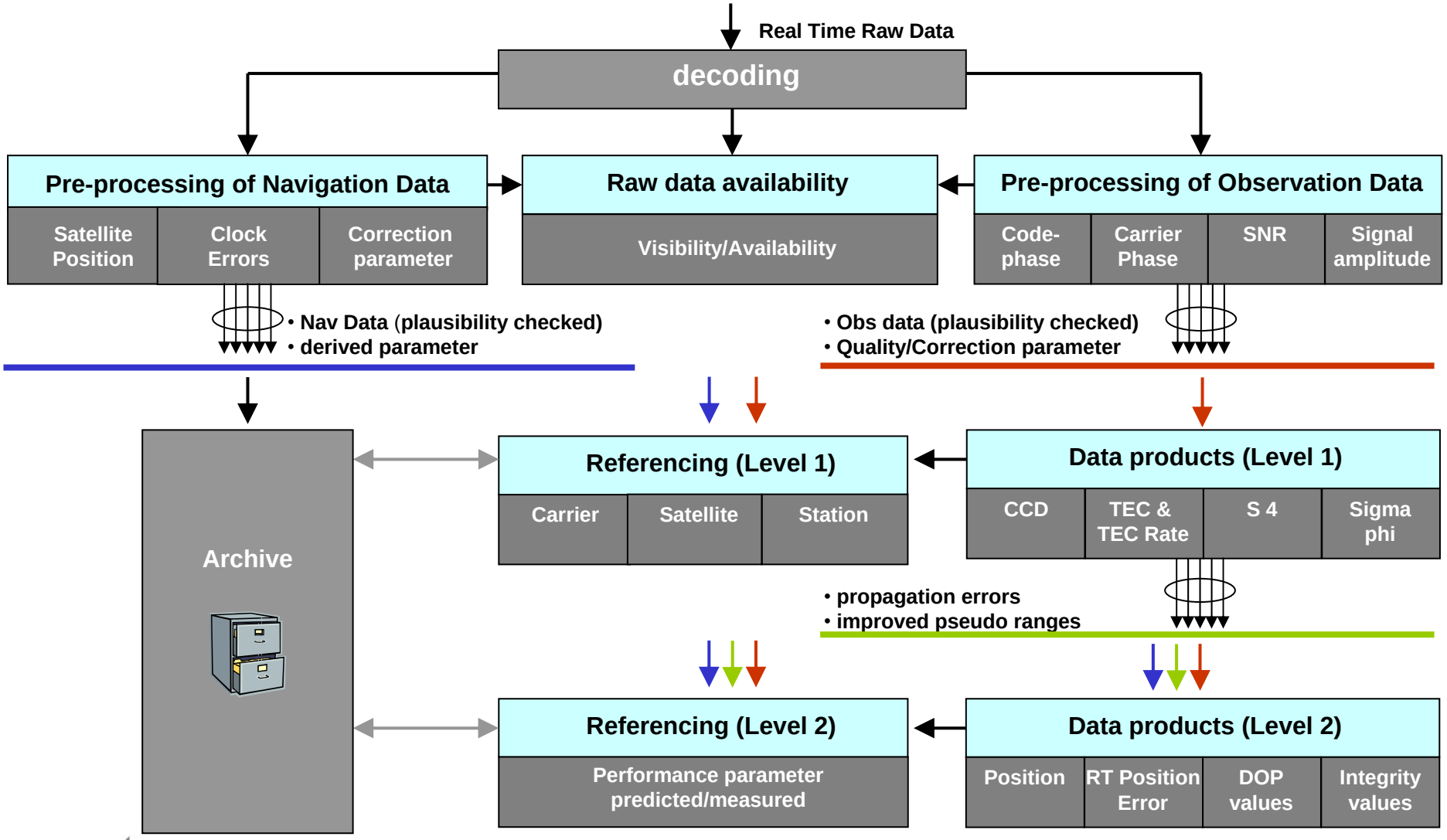
- CPCF Monitoring
- Sensor Station config.
- User configuration
- Processor config.
- Archive configuration

- Status information
- Sensor properties
- Sensor configuration
- Archive settings

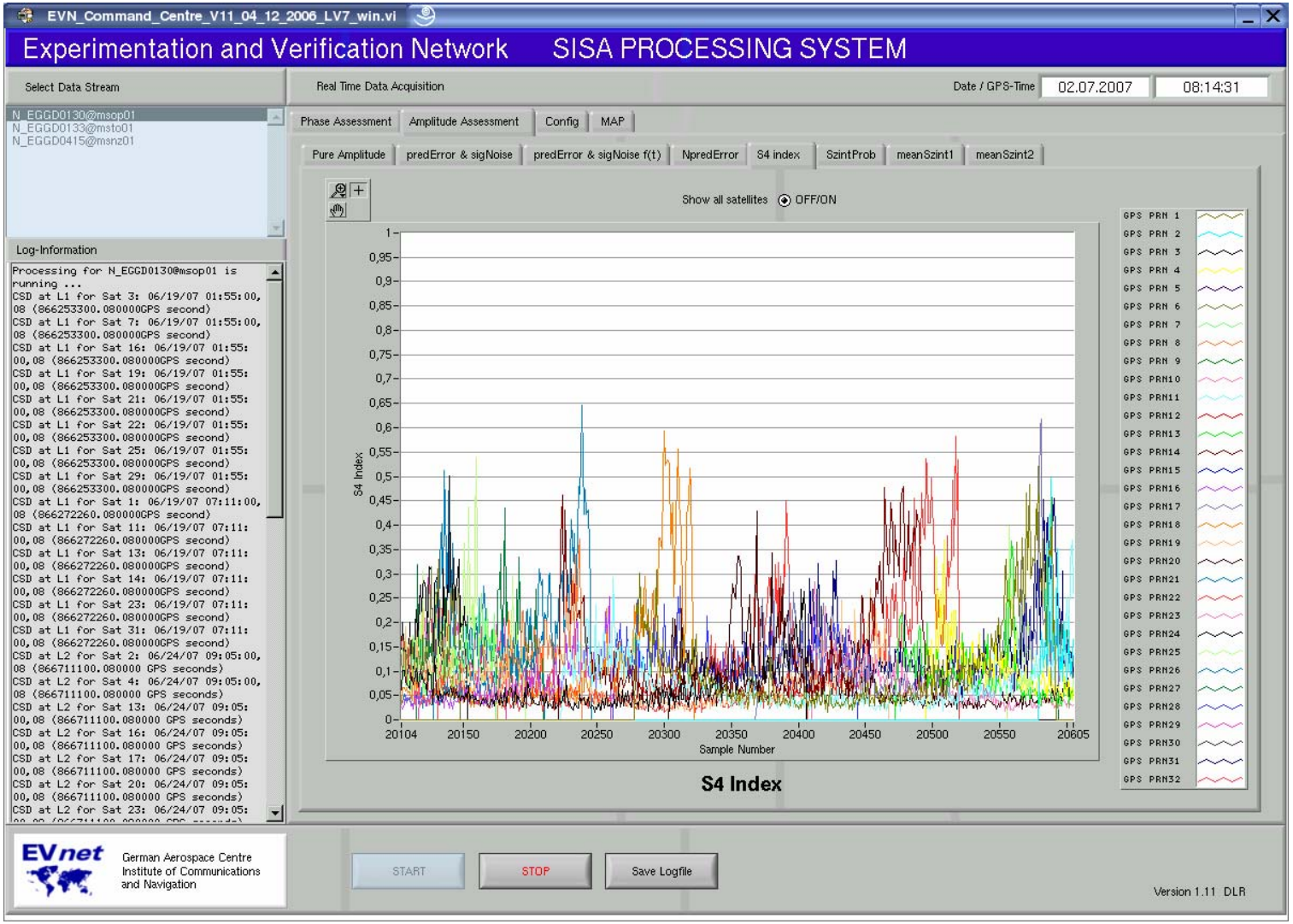
- Logging information
- Error detection
- Warnings

EVN GUI.lnk

EVnet – RT Processing and Analysis System



EVnet – RT Processing and Analysis System



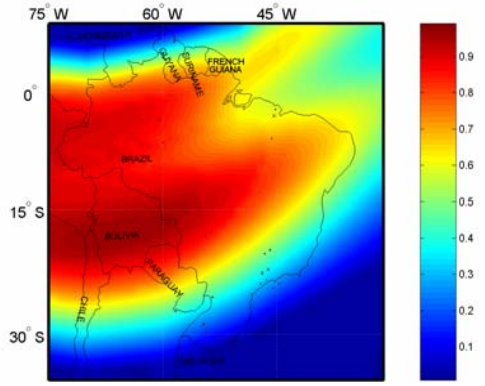
Development of a Scintillation Monitoring Network

Project: **PRIS (Prediction of Ionospheric Scintillations)**
Type: **ESA - ARTES 5 (ITT AO/1-4864/05/NL/LvH)***
Duration: **24 months (01/2006 – 01/2008)**

Partner:

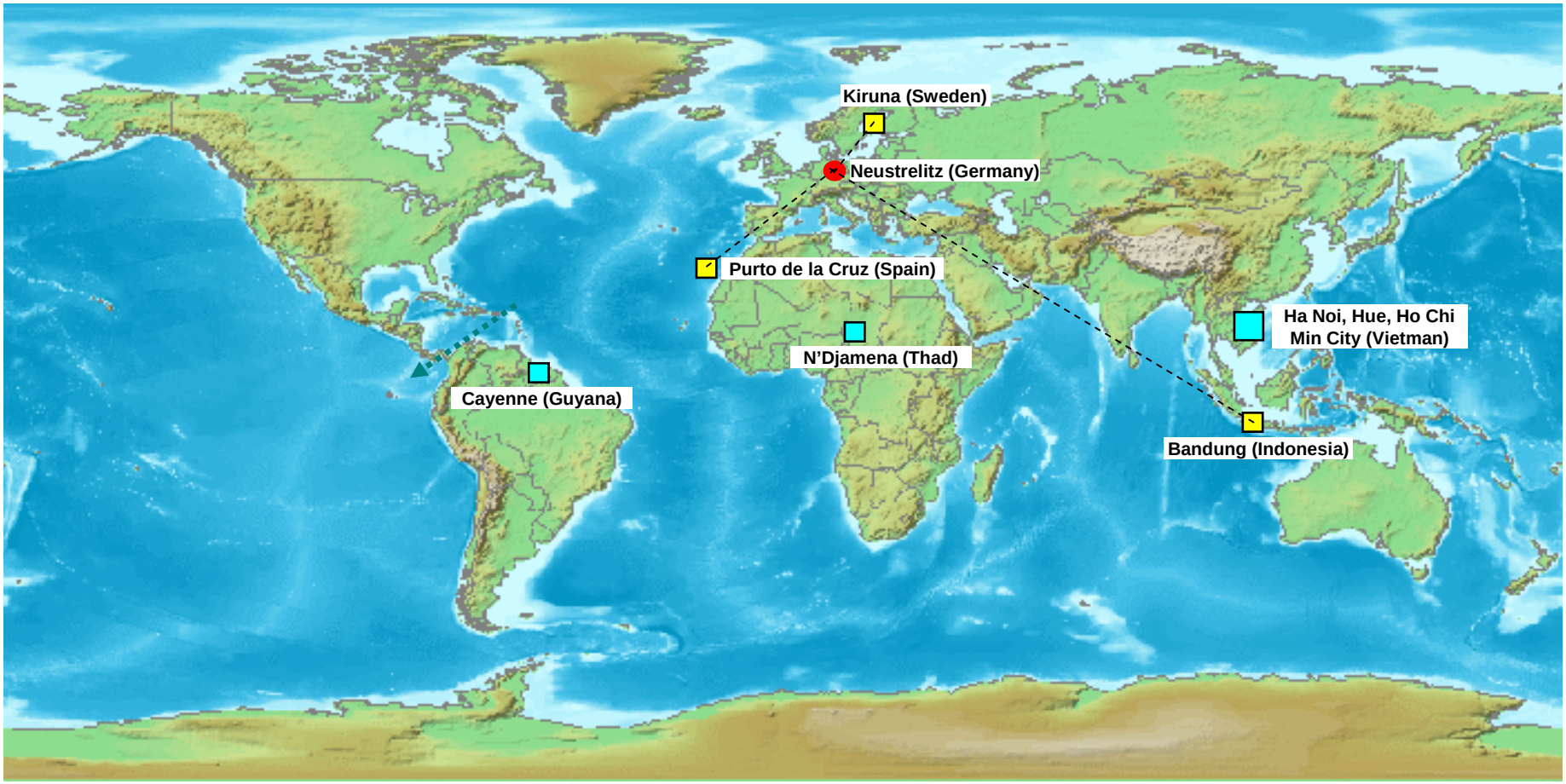
Main Tasks:

- Deployment of scintillation monitors
- Installation and operation of the scintillation Receivers at high and low latitudes
- Realization of a measurement campaign to collect a comprehensive data base
- Improved model development



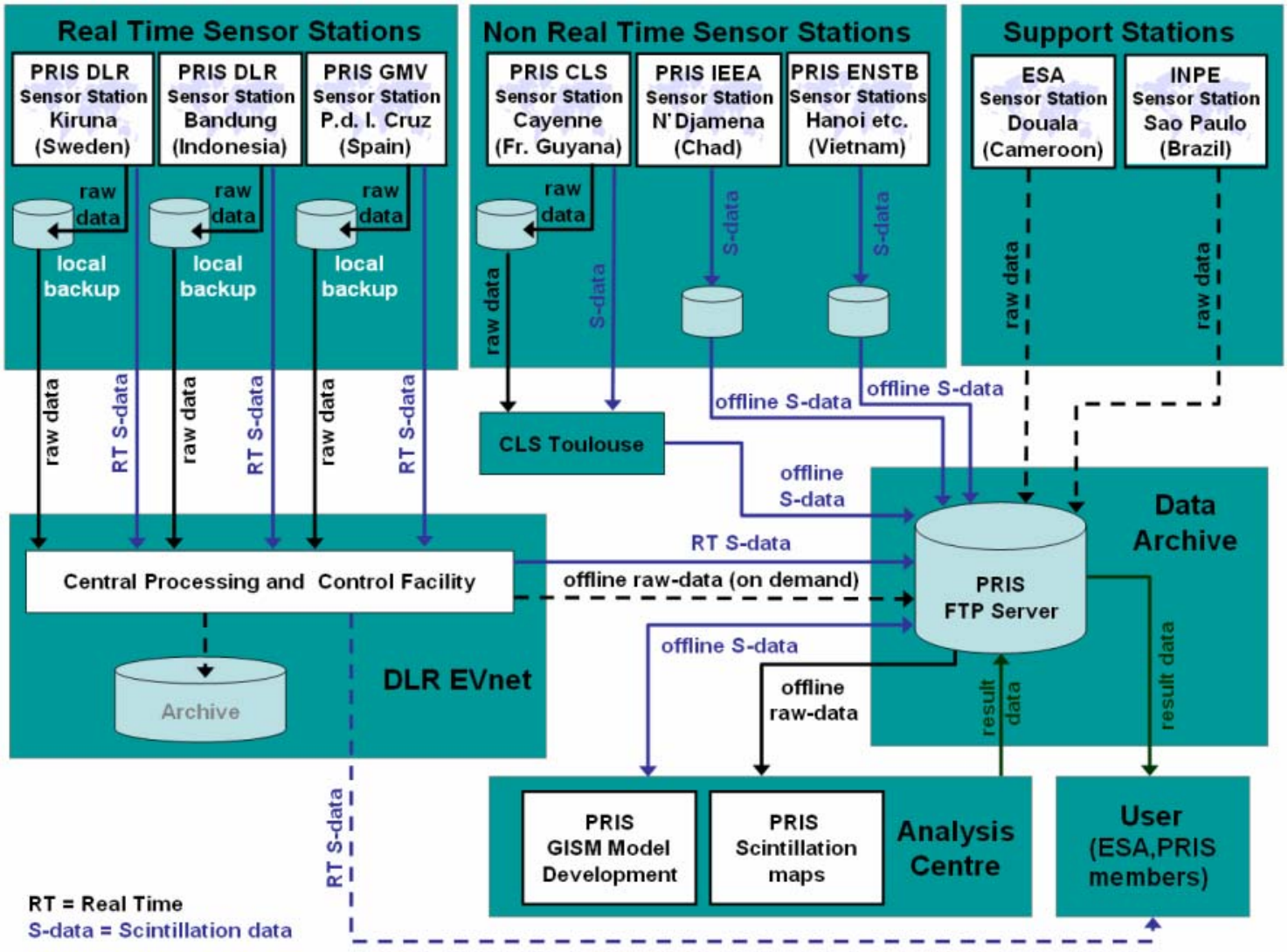
* **ESA Contract N° 19530/05/NL/LvH**

PRIS - Real Time Measurement Network based on EVnet

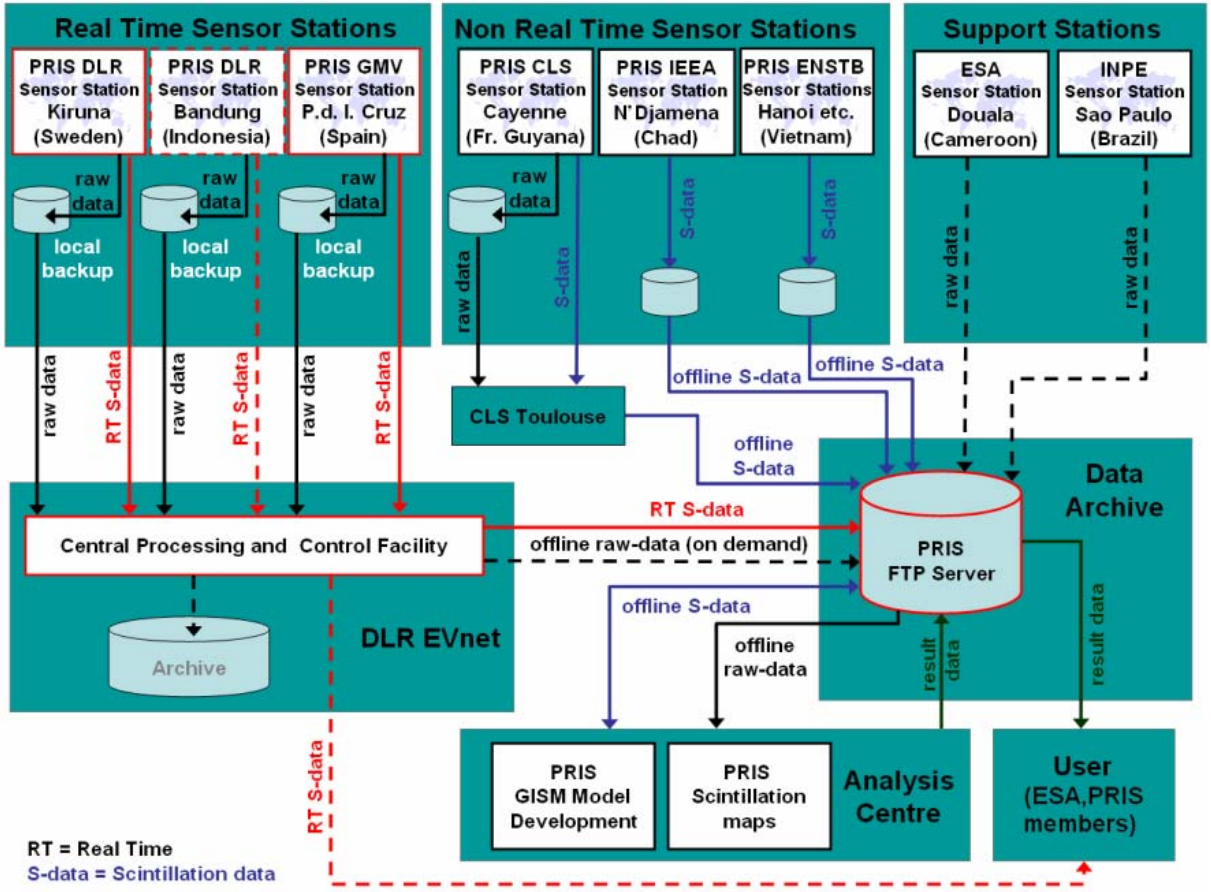


- EVnet Sensor Station (online mode)
- Sensor Station (offline mode)
- Central Processing & Control Facility (CPCF)
- Real Time Data Streams

PRIS - Data Collection and Processing Centre



PRIS - Real Time Capability via EVnet



- Demonstrates the possibility to develop a network based **scintillation monitoring** system
- Scintillation data are transmitted by using **Internet streaming technologies**
- Enables access for users to acquire **real time scintillation data** via EVnet client module
- **Operational requirements**

OS: Linux Suse
Windows 2003 Server
Windows XP

Internet connection → unblocked ssh connection via ports 22 and 8101

very small bandwidth due to the transmission of limited processing data (< 100 Byte/s)

PRIS – SW Technology supported by EVnet

SW
EVnet Sensor Station Kernel

SW
GMV EVnet / PRIS Processor

EVnet / PRIS Sensor Station

EVnet CPCF

PRIS FTP Server

SW
EVnet /PRIS Data Storage Client

EVnet / PRIS Operator

SW
EVnet /PRIS Remote Monitor

EVnet Sensor station kernel enables the capability to process and distribute data via EVnet.

GMV processor acts as an EVnet virtual sensor to determine scintillation related data at sensor station site.

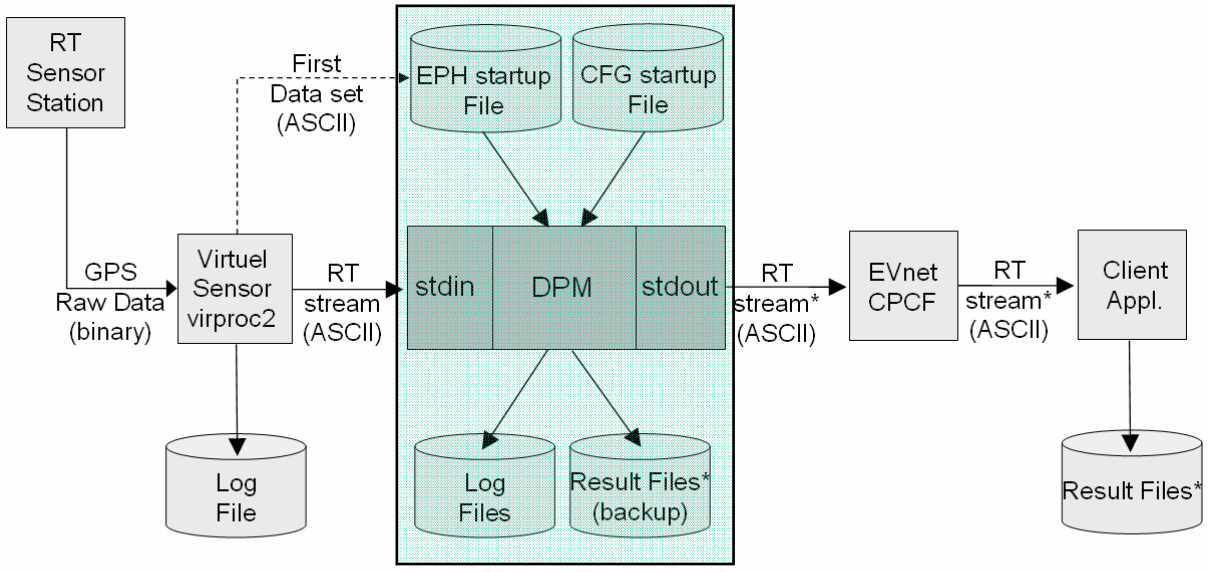
EVnet Central Processing and Control Facility (CPCF) enables user access, data broadcasting, sensor station configuration and archiving of raw data.

Data storage client is a specific application to decode and save data streams broadcasted via EVnet.

Monitoring of the EVnet/PRIS sensor stations is realized by an operator GUI to command and observe the data transmission.

SW - Software

PRIS – Scintillation processor

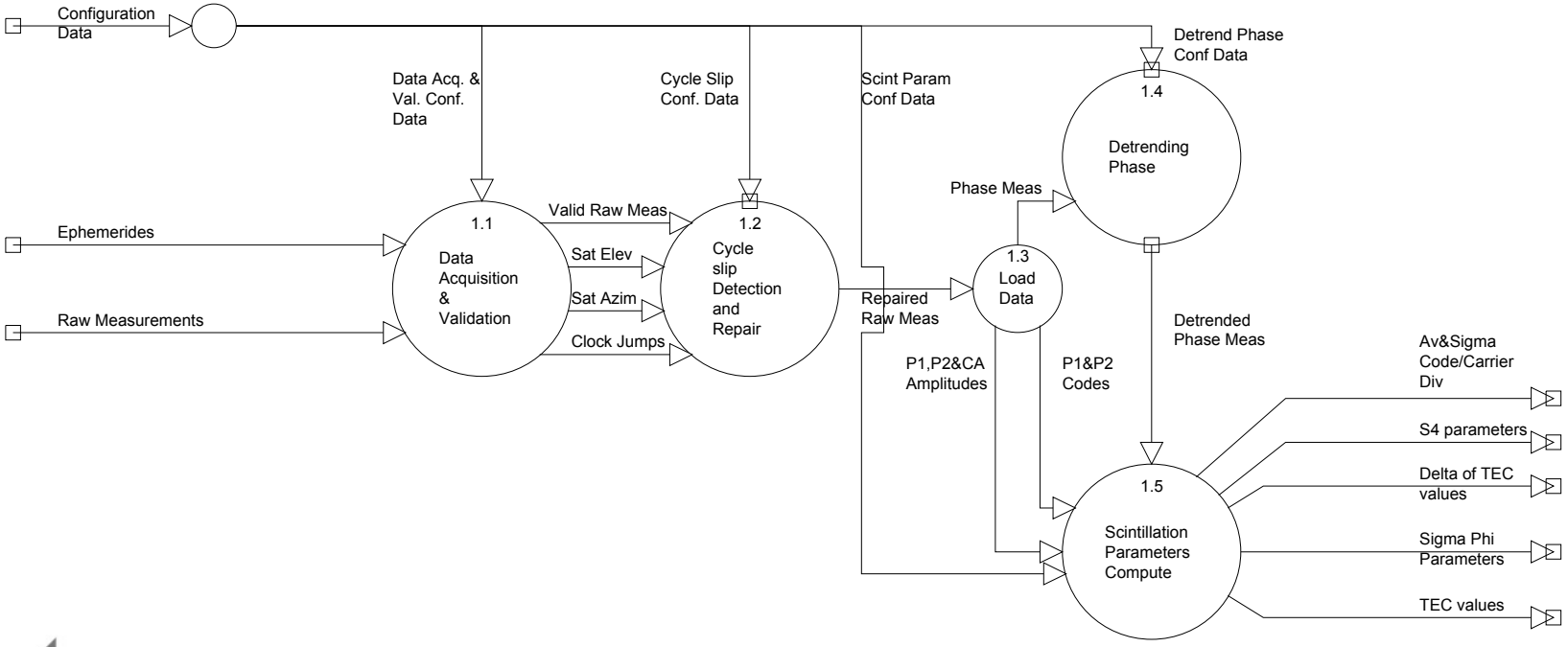


Block diagram of the processor to generate scintillation parameter

- Implemented as EVnet virtual sensor
- Input data are: GPS L1/L2 code and carrier phase pseudo-range observations, un-smoothed amplitude values, C/N0, navigation data (ephemeris, almanac)
- Output values are: scintillation related data like S4, σ phi, TEC + additional status parameter
- Generates result files as backup at each station site
- Generates data streams via Internet (EVnet)
- Generates Log-Files at station site and log messages via stream

PRIS – Data Processing Module (DPM)

- ✓ DPM developed by GMV (Spain).
- ✓ Objective : The Javad/Topcon receivers at real time sensor stations are not able to deliver scintillation based data directly (in comparison to the GSV 4004 receiver). Therefore, a specific DPM was developed to compute scintillation values based on the ASCII data stream input values (after converting the binary data coming from the receivers).



PRIS –DPM scintillation parameters

✓ Objective: Compute the following scintillation parameters for each satellite and selected period of time:

- L1, L2 and CA S4 parameters:

$$S_4 = \sqrt{\frac{\langle SI^2 \rangle - \langle SI \rangle^2}{\langle SI \rangle^2}}$$

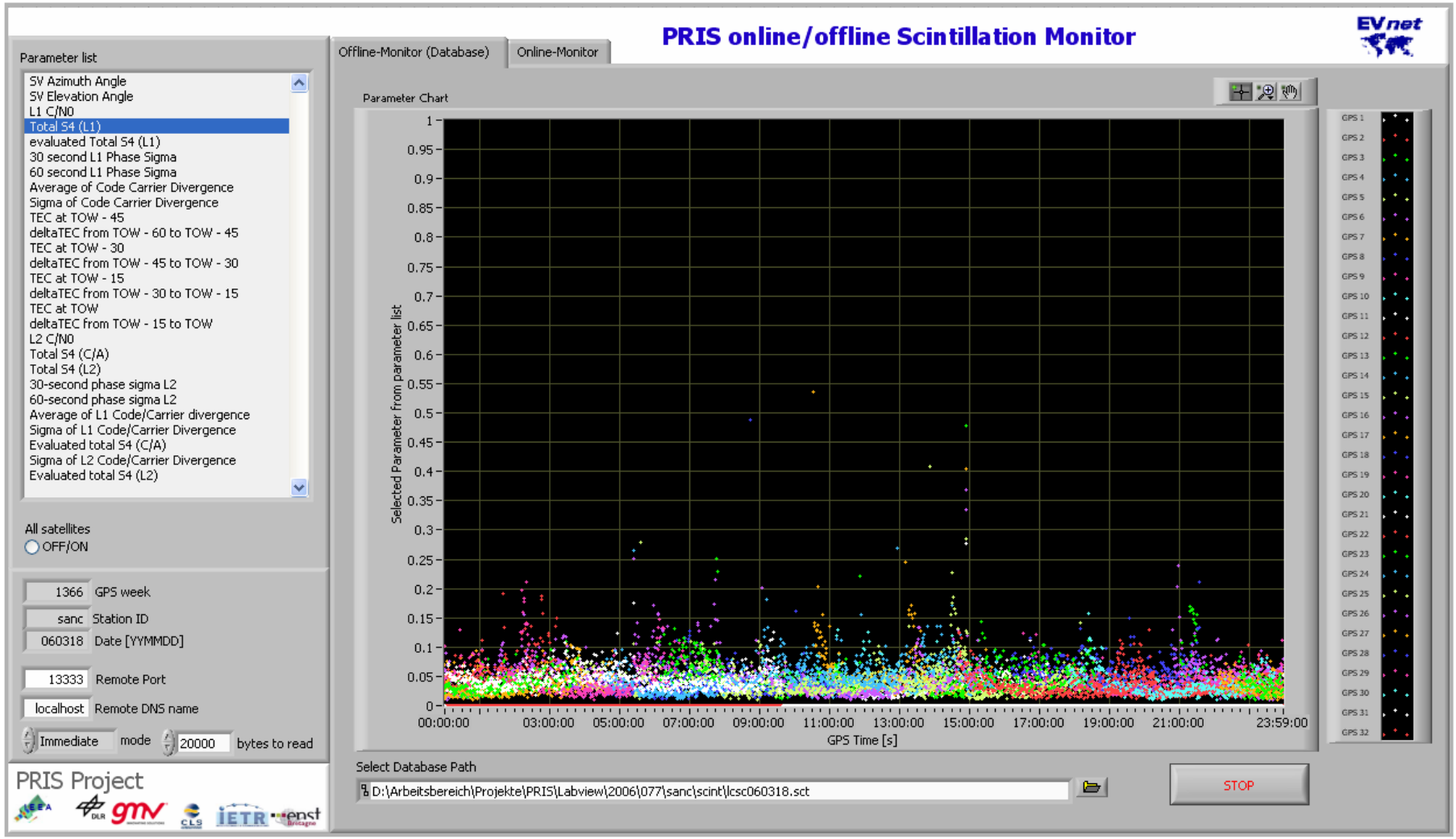
- 30 and 60s L1 and L2 Sigma Phi parameters, using a Butterworth filter
- TOW, TOW-15s, TOW-30s, TOW-45s and TOW-60s TEC values from L1 and L2 code measurements:

$$sTEC = 9.52 \cdot (PR_{L1} - PR_{L2}) + 2.86 \cdot SatDCB(ns)$$

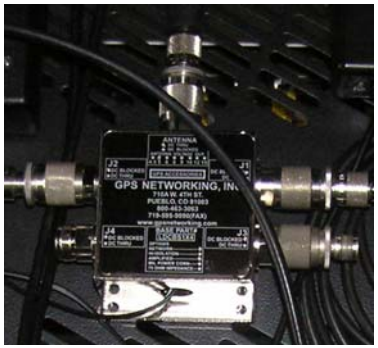
- 15s Delta of TEC values from L1 and L2 phase measurements, computed by subtracting the TEC for a selected time and the TEC value 15 seconds ago and are calculated at TOW, TOW-15s, TOW-30s and TOW-45s.
- 60s L1, L2 and CA Average and Sigma of Code/Carrier divergence.
- L1, L2 and CA corrected S4 parameters: A crucial CCD std value is considered:

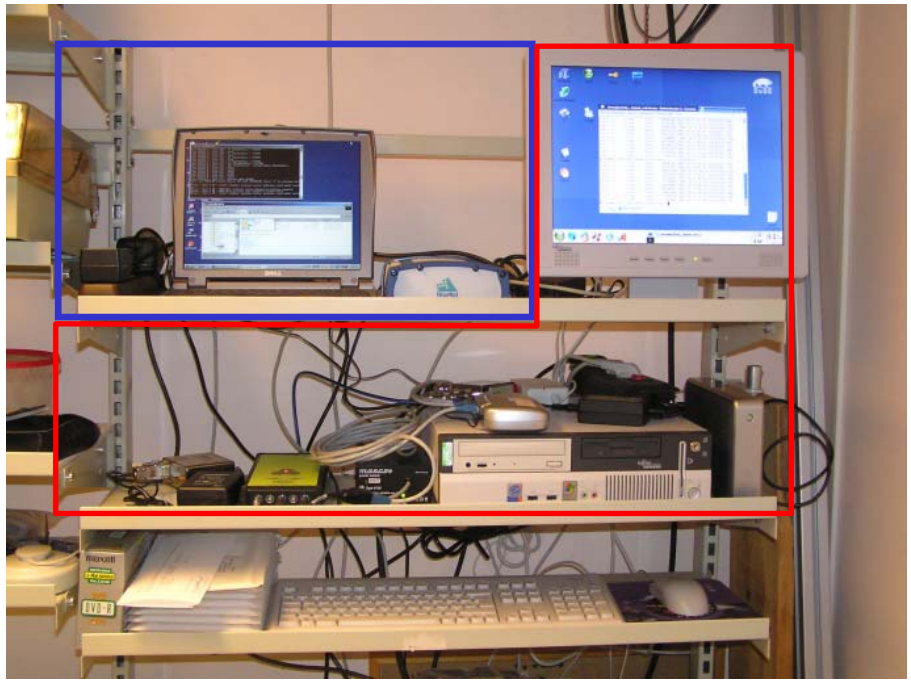
$$CCDstd(crucial) = A \cdot S4 + B$$

PRIS – Scintillation monitor

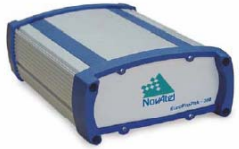


Comparison test campaign in Kiruna





GPS Ionospheric Scintillation and TEC Monitor (GISTM)



Novatel GSV4004B (50 Hz L1/L2 GPS)

DLR/GMV scintillation monitoring system

Javad Legacy EGGD2 (50 Hz L1/L2 GPS/GLONASS)

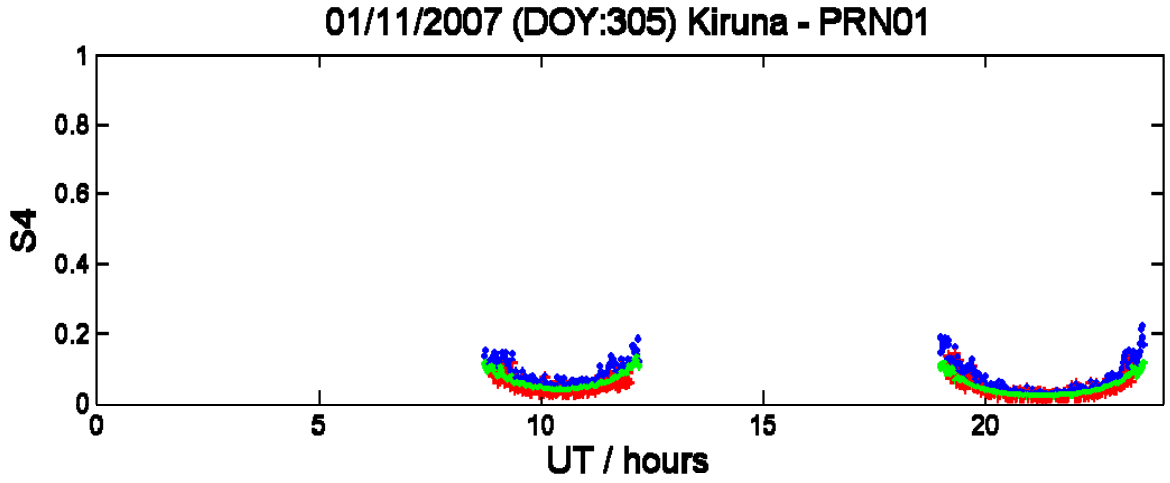
Antenna: Javad REGANT

Antenna-splitter: GPS networking

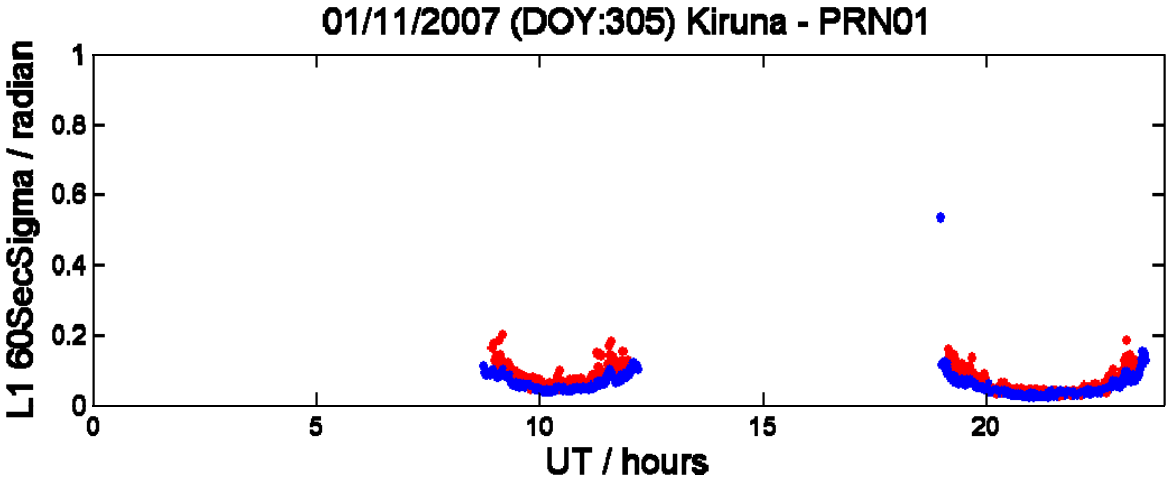
Start: 10/2007

Generation of daily scintillation parameter for both receivers

Test campaign results

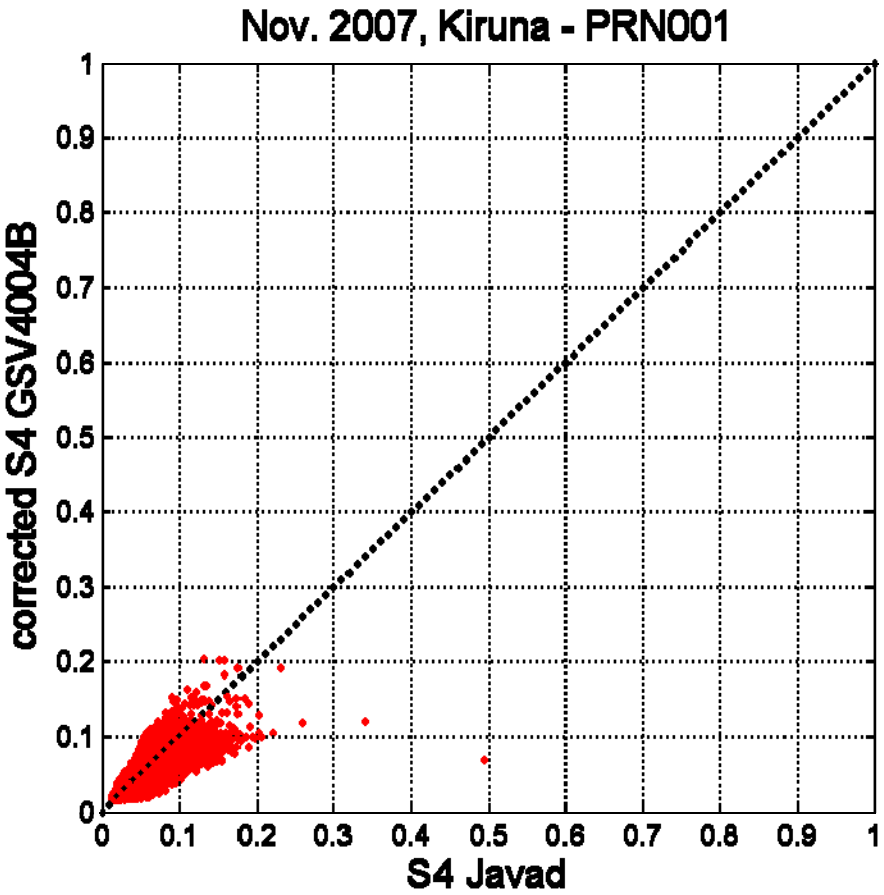


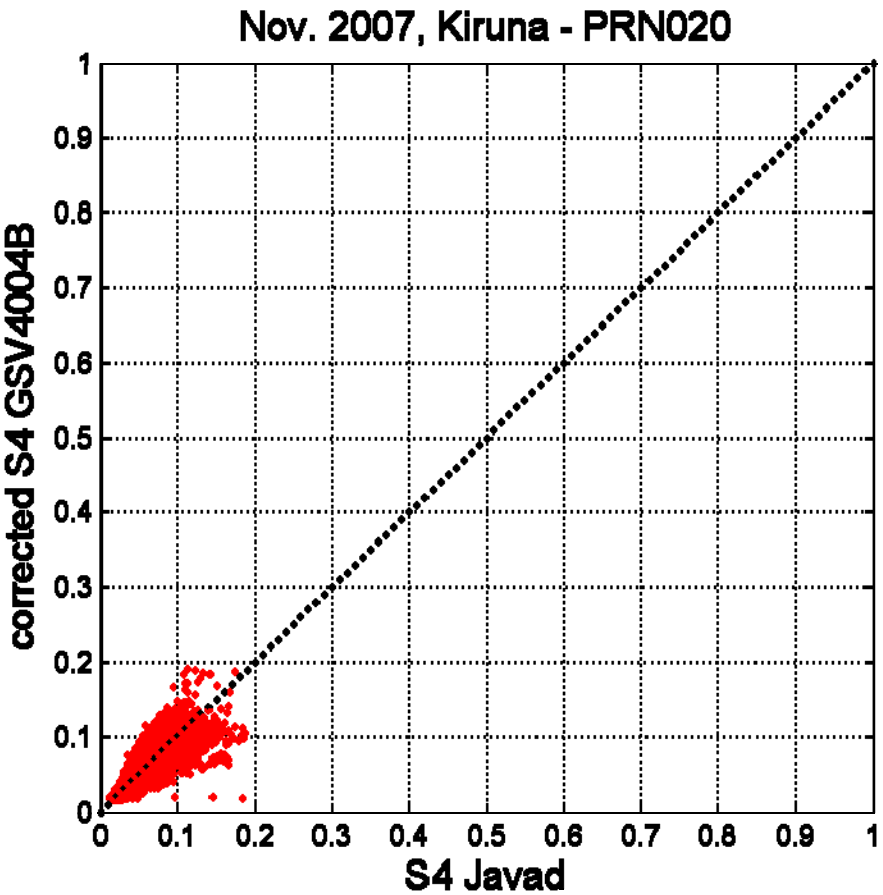
Javad
GSV 4004 (S4 un-corrected)
GSV 4004 (S4 corrected)



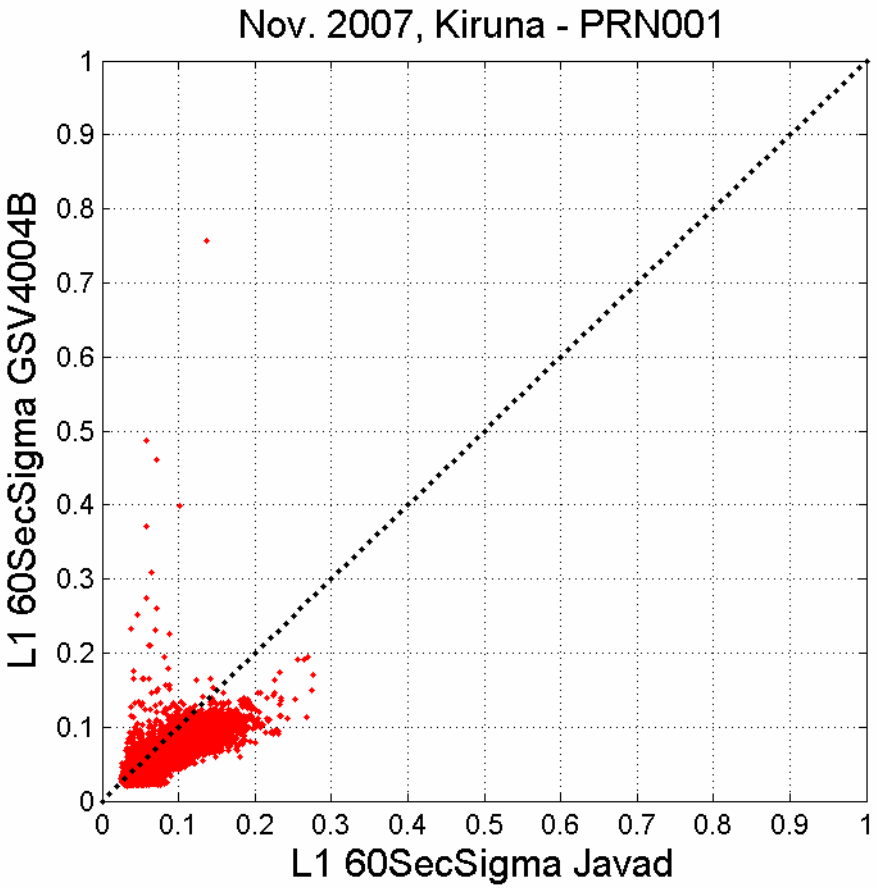
Javad
GSV 4004

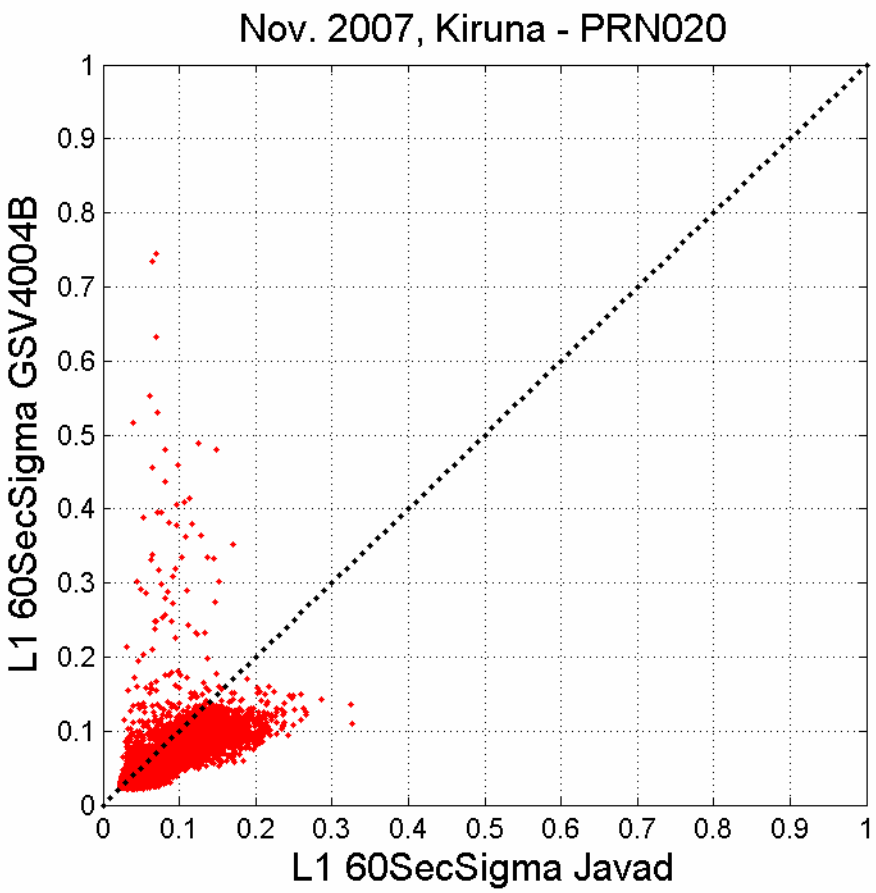
Test campaign results (scatter plot S4)





Test campaign results (scatter plot L1 60secSigma)





Conclusions

- It has been shown that EVnet comes with features to support the monitoring, processing and distribution of ionospheric related parameter
- EVnet offers the possibility to build a network of monitoring stations with small effort and in a very easy manner
- As part of the ESA project PRIS the EVnet was used as data collection and processing centre under real time aspects
- To observe the ionospheric behaviour at different sites in real time a prototype of a scintillation monitor was developed
- Beside this a comprehensive data base is available to improve the ionospheric scintillation model development